VEHICLE/PROJECT INTERFACE ANALYSIS

Seattle Streetcar-Center City Connector

Prepared for:

Seattle Department of Transportation

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Executive Summary

1 BACKGROUND & PURPOSE

1.1 PURPOSE

The purpose of the Vehicle/Project Interface analysis is to identify conflicts between proposed CAF Urbos vehicles and existing or proposed streetcar infrastructure; identify potential design solutions; assess feasibility; and develop preliminary cost estimates. The analysis is intended to provide a level of detail sufficient to support decision-making by the City.

1.2 BACKGROUND

The Seattle Streetcar system currently consists of two segments, the South Lake Union Streetcar (SLU) line and the First Hill Streetcar (FHS) line, which operate independently and are served by separate streetcar vehicle fleets that are stored and maintained at separate facilities, known as Operations and Maintenance Facilities (OMF). The SLU line operates with a 4-vehicle fleet from the SLU OMF, located at Fairview Avenue N and Harrison Street. The FHS line operates with a 6-vehicle fleet from the FHS OMF, located at 8th Ave S and Dearborn Street. All of the vehicles in the SLU and FHS fleets were manufactured by Inekon, a Czech company. Three of the SLU vehicles were delivered in 2007 and are conventionally powered through an overhead contact system; one of the SLU vehicles and the six FHS vehicles were delivered in 20015 and are powered both conventionally through an overhead contact system, and with a battery system that allows off-wire operation. The ten Inekon vehicles are essentially identical in dimensions such as length, width, height, and in the configuration of elements such as doors, powered trucks, and propulsion equipment; the newer generation vehicles, with battery-drive systems, are each approximately 3,000 pounds heavier than the first-generation vehicles.

The City of Seattle, through its Seattle Department of Transportation (SDOT), is currently in the capital project delivery process for a third streetcar segment, the Center City Connector, that would link the two existing segments. The proposed operating plan for the completed Seattle Streetcar system is anticipated to require a 17-vehicle fleet, in which all of the vehicles would have the battery-drive systems that allow for off-wire operation in segments of the system that do not have access to power via an overhead contact system. (SDOT is considering potential revisions to the operating plan, which currently envisions two lines of services that would overlap through the Center City Connector segment. However, all potential operating scenarios require that all vehicles have battery-drive capability.) The City is under contract with CAF, a Spanish company, for the delivery of 10 “Urbos” model streetcars with off-wire capability. The future system fleet, therefore, is planned to consist of ten CAF streetcar vehicles and seven Inekon streetcar vehicles.

There are several differences between the proposed CAF streetcar vehicles and the Inekon streetcar vehicles including:

- Length: CAF vehicles are approximately 9’ longer;
- Weight: CAF vehicles are heavier, exceeding the weight of the Inekon vehicles by approximately 12 tons;
- Dynamic envelope, which affects the clearances required between operating vehicles and roadway features such as station platforms and curbs; and
- The configuration and points of access to components mounted on the vehicles, which impacts the requirements for OMF configuration and equipment.

2 SCOPE & APPROACH

2.1 SCOPE

The scope of the analysis included evaluation of the following streetcar system elements:

Track:	Confirm that the CAF vehicle dynamic envelope will not introduce clearance conflicts with fixed objects on the wayside (signs, trees, curbs, etc.); confirm vehicle/track interfaces
Platforms:	Address accessible boarding zone compatibility and potential impacts to crosswalks, driveways and on-street parking

Tail Tracks:	Evaluate the feasibility of extending the existing Fairview & Campus Drive and Broadway & Denny end-of-line "tail" tracks as may be required to accommodate the length of the CAF Urbos streetcar vehicles
OMF:	Evaluate adequacy of the storage capacity of the SLU and FHS OMF, including planned improvements to the SLU OMF; evaluate systems, vehicle access and maintenance equipment requirements for the CAF Urbos streetcar vehicles
Bridges:	Evaluate the structural adequacy of the bridge structures supporting S Jackson Street between 2nd Avenue Extension and 5th Avenue S and the ability to accommodate the weight/dynamic load of the CAF Urbos streetcar vehicles

For each of these elements, where conflicts or deficiencies were identified, potential design solutions were identified, evaluated as to feasibility, and developed to the conceptual design level to support cost estimating.

2.2 APPROACH

The analysis included review of as-built drawings of existing streetcar system elements; field review, and coordination with King County Metro's streetcar operations division and SDOT's traffic engineers and structural engineers. Bridge structures were evaluated using a load rating scaling method (dependent upon previous analyses). Next steps to progress beyond conceptual design solutions are anticipated to include survey of the existing streetcar facilities to confirm any critical dimensions, load rating of the affected bridge structures (including, potentially, live-load testing of the bridge structures), and progressing each conceptual design solution through preliminary engineering and final design.

3 SUMMARY FINDINGS—FEASIBILITY & COST

3.1 FEASIBILITY

Feasible design solutions were identified for all vehicle/project interface conflicts, as described further in sections 4 through 8 below.

3.2 COST

A range of potential costs, including contingencies and escalation to the year 2022, were identified for each affected element. The range of total cost for all of the improvements to address vehicle/project interface, is $11 M to $17.4 M, in 2022 dollars. Cost by element and cost estimating methodology are described further in section 9 below.

4 TRACK CLEARANCES & INTERFACE

4.1 CLEARANCES

As rail vehicles move through curves and grades in an alignment, they sway, so that the "envelope" of the path they move through is dynamic and varies with the radius of curves, speed, and other factors. The analysis confirmed that the CAF Urbos dynamic envelope is a smaller envelope than that of the Inekon vehicles (with one exception, outswing on tight curves. Tight curves were checked by CAF to confirm that there are no clearance issues. CAF noted a possible exception at the 8th and Jackson turnout to the single track leading to the FHS OMF. However, this is already addressed by an operating rule in existing operations—vehicles can only access the turnout after confirming that there are not conflicting mainline vehicles present.

4.2 TRACK GAUGE

Most rail transit systems use a standard gauge of 4' 8.5"" (1435 mm). This simplifies the process of procuring rail vehicles and confirming wheel-to-rail interface. After the City of Portland pioneered the reintroduction of streetcars in the U.S. with the Portland Streetcar in 1999, engineers there observed that the streetcar wheels were experiencing rapid wear and generating more noise through turns than expected. As the Portland Streetcar system expanded, the system's engineers determined that a slight narrowing of the track gauge in turns would improve wheel wear and reduce noise from the streetcars, which were Czech-built cars of the same design as those later procured in Seattle. This

track design refinement, to a gauge of 4' 8.25" (1428 mm) in tight curves was implemented in the design of curved track for the first Seattle Streetcar segment (the SLU line). For the second segment, the FHS line, this refinement was adopted for both tangent (straight) and curved track. The design of the Center City Connector segment proposes to continue the use of this modified standard gauge. Currently, the new generation of Inekon vehicles operate on both the SLU and FHS line, with no adverse impacts observed to date associated with track gauge.

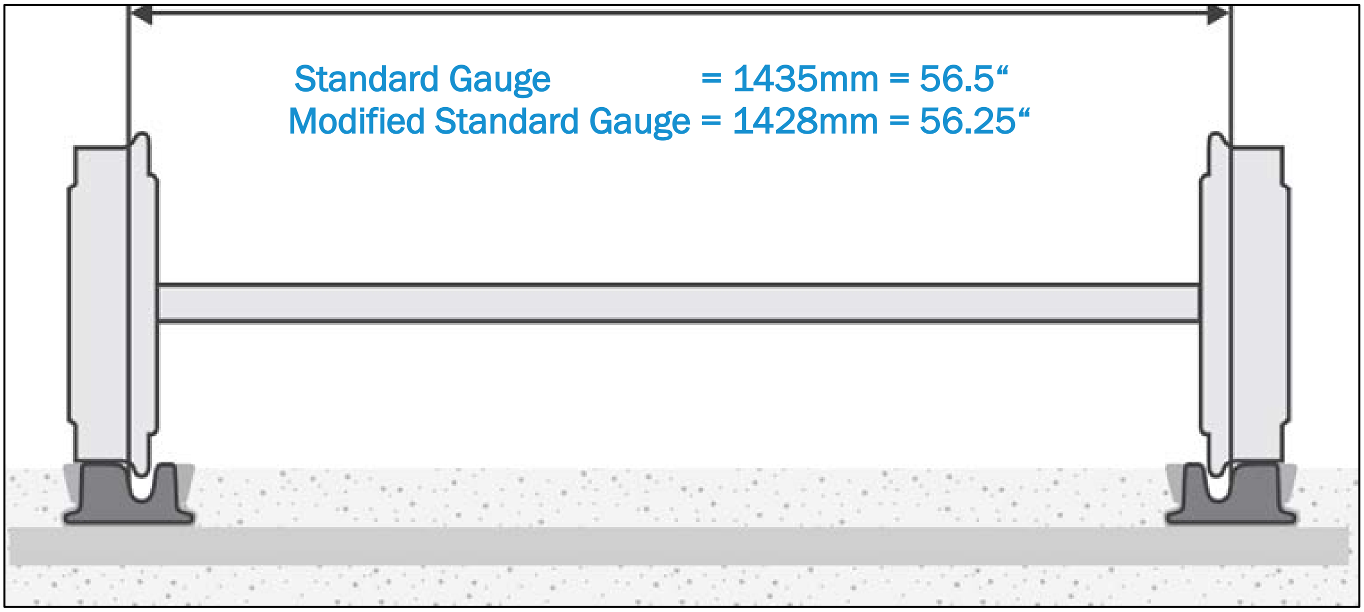

Figure 1 Seattle Streetcar vehicles currently operate on both standard gauge and modified standard gauge track.

The modified standard gauge was developed to improve wheel wear and reduce noise.

Figure 2: Existing and proposed track gauge on Seattle Streetcar segments.

5 STATION PLATFORMS

5.1 STATION PLATFORM CHARACTERISTICS

Passengers access the Seattle Streetcar at any of twelve stations on the SLU line or fourteen stations on the FHS line. Five additional platforms are proposed for the Center City Connector segment. These platforms vary in their placement within the roadway (side or center) and in their length and width. Each platform is a custom design tailored to fit within its context, such as nearby driveways, existing street trees, and on-street parking. However, common features of the station platforms include curbs at a height of approximately 10" through boarding locations to provide near-level boarding; level grading at boarding zones to accommodate deployment of "bridge plates" for accessible boarding; and berthing markers that allow streetcar operators to identify the appropriate stopping location to align vehicle doors with boarding areas.

Figure 3: Streetcar station platforms provide a raised curb and level boarding areas for accessible boarding.

5.2 STATION PLATFORM MODIFICATIONS

To identify potential conflicts at platforms, dimensional representation of the CAF and Inekon vehicles were aligned in plan view with the platform plans or as-built plans. At most platforms, no significant conflicts are anticipated. Five platforms will require modifications, typically platform extensions, as shown in the example in Figure 4 below. The total cost of these modifications is estimated to be $500,000, inclusive of estimating contingencies and escalation to year 2022.

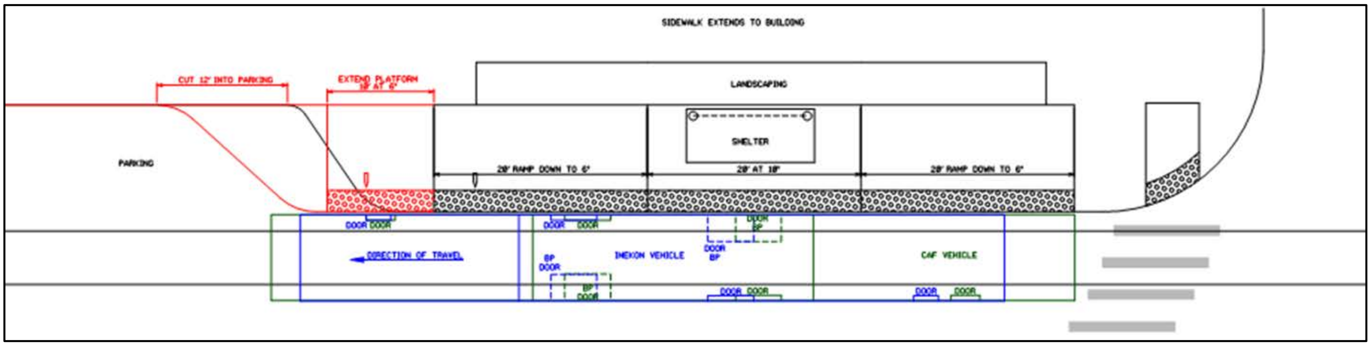

Figure 4. Platform/vehicle analysis and conceptual design solution for Westlake and 7th Northbound streetcar platform. The dimensions and door locations of the CAF and Inekon vehicles are shown in green and blue, respectively.

6 TAIL TRACKS

6.1 TAIL TRACK CHARACTERISTICS

The SLU and FHS lines each feature a "tail track" end of line configuration, in which the inbound and outbound tracks of the mainline converge through a switch (or "turnout") into a single track. This arrangement allows for efficiently reversing the direction of the vehicle. The analysis evaluated the storage length of the tail tracks at SLU (Fairview Avenue at Campus Drive) and FHS (Broadway at Denny Way) for compatibility with the operational requirements of the expanded system after construction of the Center City Connector. In addition to requirements during normal operations, the analysis considered contingency operational requirements for temporary storage and towing of disabled streetcar vehicles. King County Metro's streetcar operations division provided input on the normal and contingency operations requirements. Figure 5 provides a graphical representation of the analysis as applied to the Broadway and Denny Tail Track.

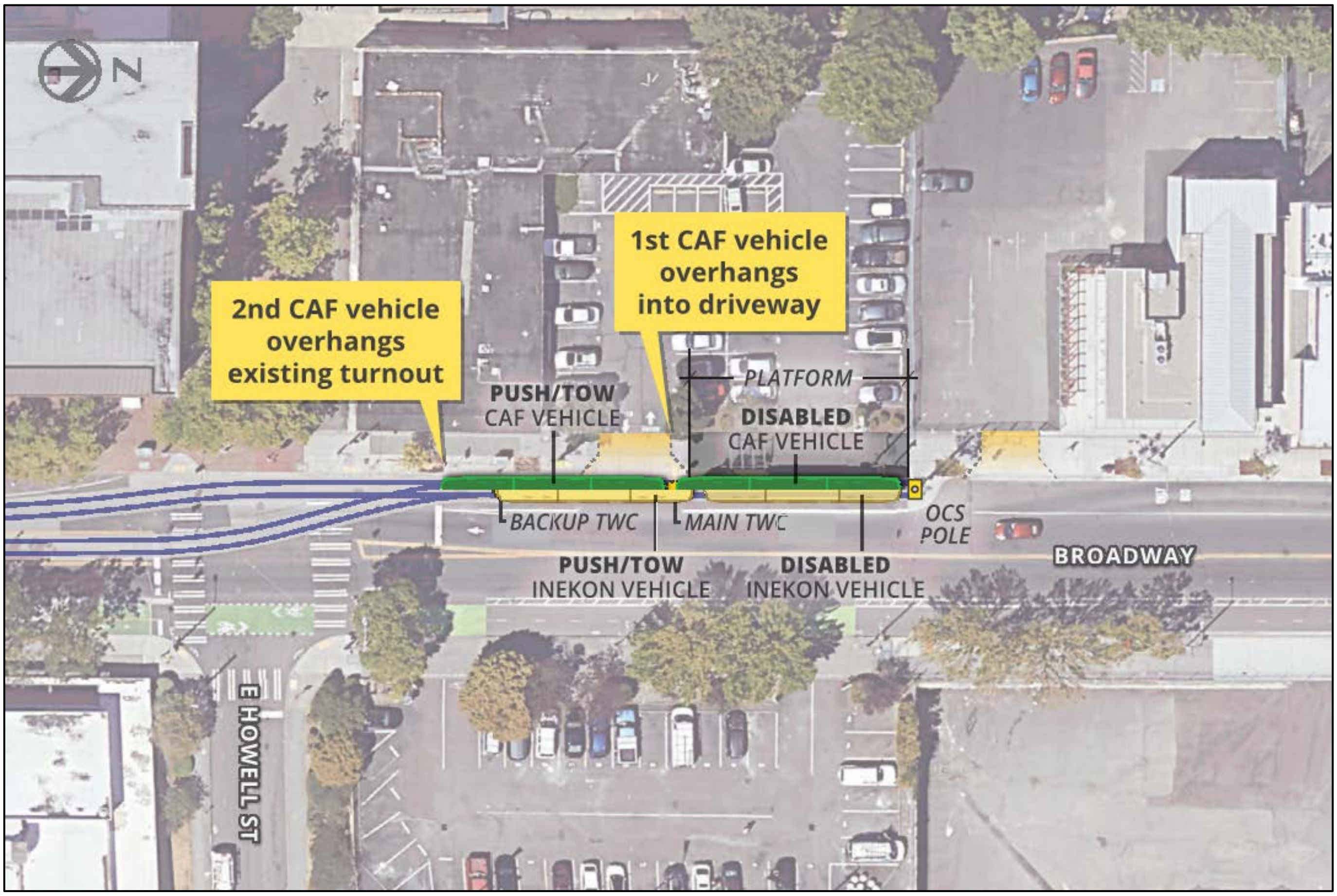

Figure 5: In an operational scenario requiring temporary storage and towing of a disabled streetcar, the proposed CAF streetcars would present several conflicts at the existing First Hill Streetcar tail track on Capitol Hill.

6.2 TAIL TRACK MODIFICATIONS

The SLU and FHS tail tracks each require modifications to accommodate contingency operations with the proposed CAF streetcar vehicle, as shown in Figures 6 and 7 below. The total cost of these modifications is estimated to range from $500,000 to $800,000, inclusive of estimating contingencies and escalation to year 2022.

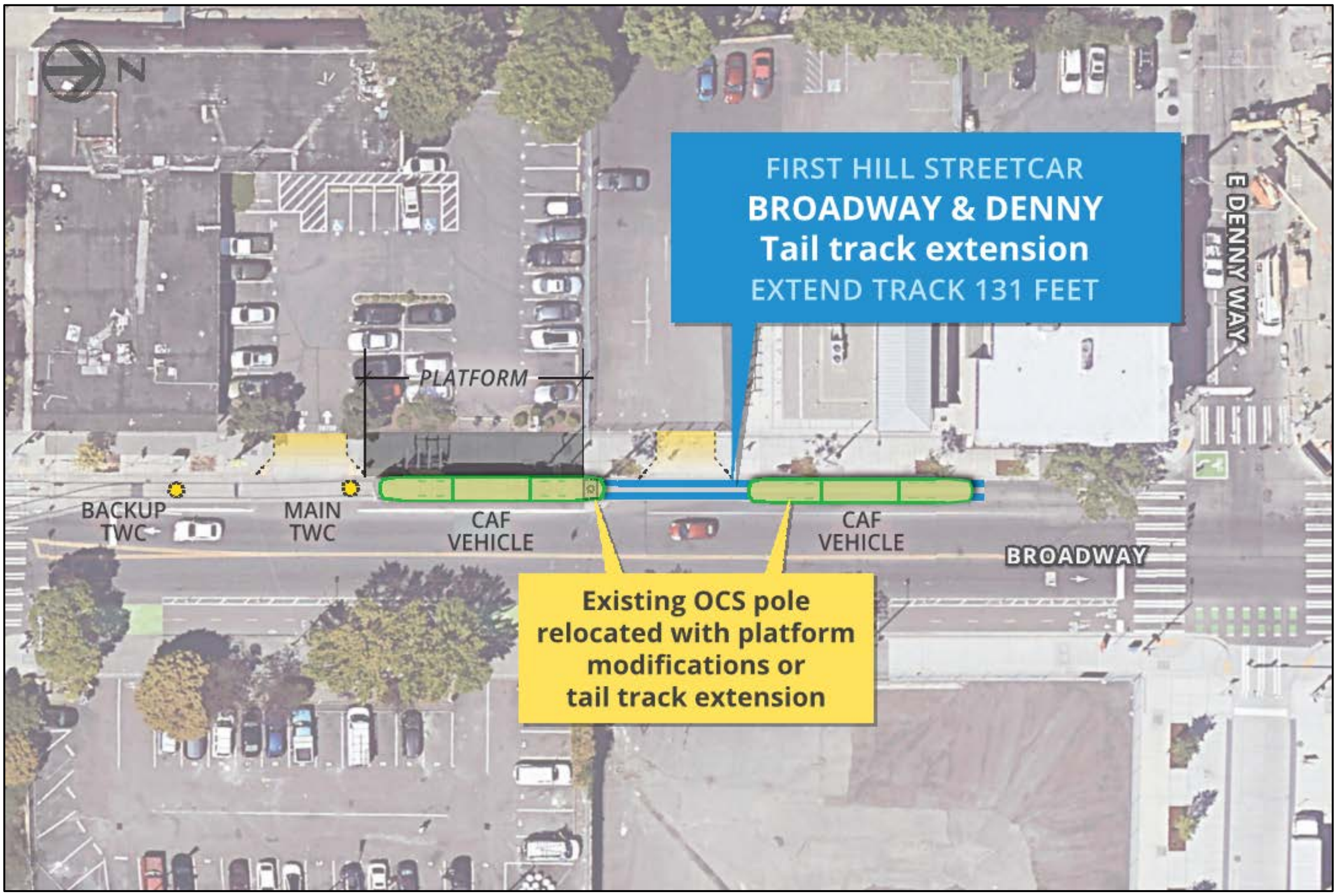

Figure 6: Conceptual design of modifications to the Broadway and Denny tail track.

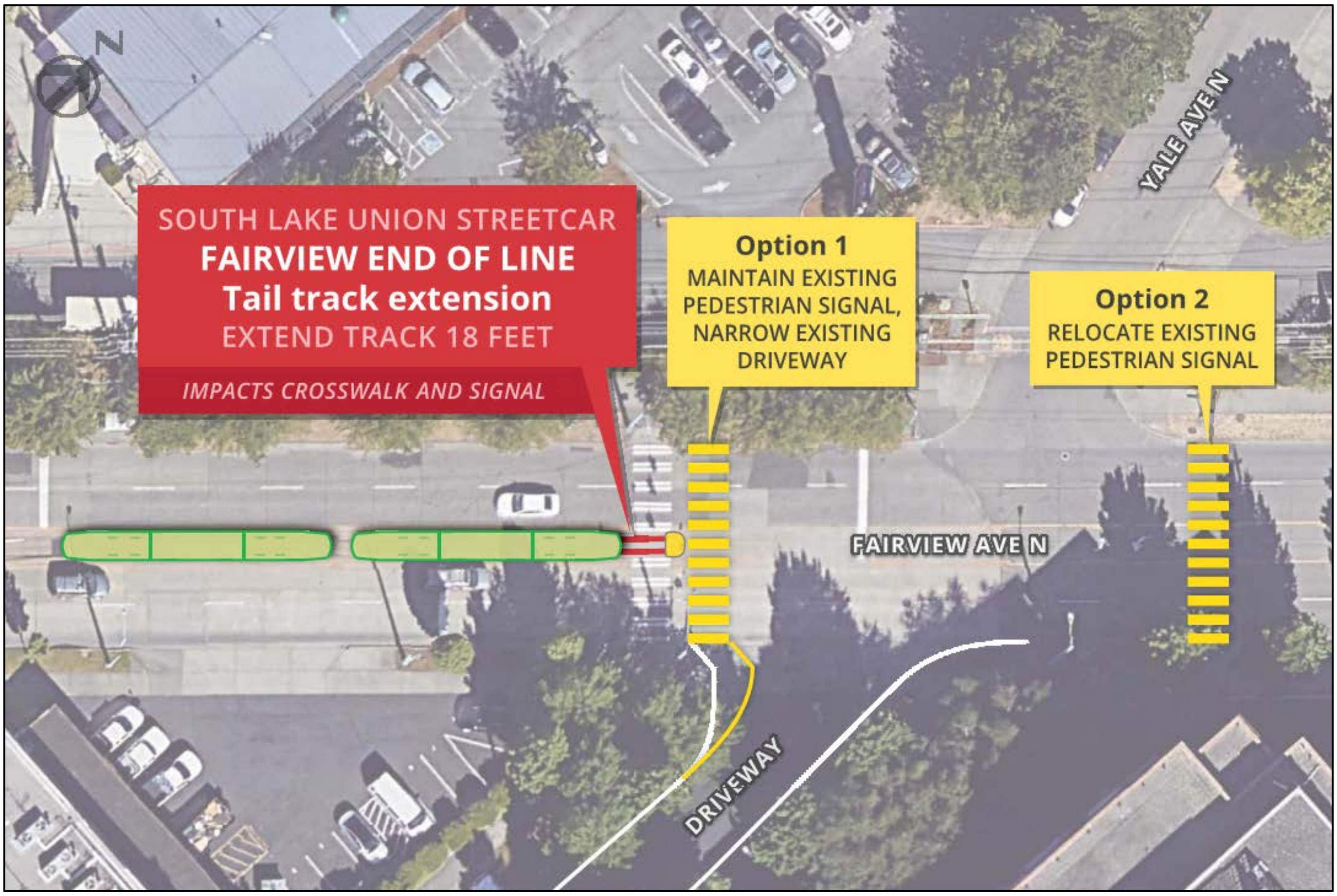

Figure 7: Conceptual design options for modifications to the Fairview and Campus Drive tail track.

7 OPERATIONS & MAINTENANCE FACILITY

7.1 OMF CAPACITY & COMPATIBILITY

With respect to operations and maintenance of the Seattle Streetcar fleet, the analysis addressed two issues: storage capacity, and compatibility of facilities and equipment for performing required vehicle maintenance. The scope of the proposed Center City Connector project includes expansion of the SLU OMF to provide additional vehicle storage capacity and to expand the facility to provide space for additional staff, spare parts and equipment. The proposed OMF expansion was designed prior to the selection of the CAF Urbos streetcar vehicles. The CAF vehicles are longer than the vehicles in the current fleet, and also differ in various industrial engineering requirements, such as the equipment and methods required for lifting the vehicles with jacks, and the configuration of the maintenance pit required for access to under-mounted equipment (axles on the CAF vehicles are configured differently from those on the Inekon vehicles, requiring a wider pit for side access to the wheels and powered axles).

The design team developed conceptual designs for a revised track layout and construction of an additional (third) maintenance position configured for the CAF vehicles, with input from King County Metro staff responsible for operations and maintenance of the Seattle Streetcar. The concept design provides capacity to store and maintain all ten of the proposed CAF vehicles at the SLU OMF. Key features of the conceptual design solution are shown in Figure 8 below. The incremental cost of these modifications (in excess of the estimated cost of the baseline OMF expansion design proposed for the Center City Connector) is estimated in the range of $5.6 M to $5.8 M, inclusive of estimating contingencies and escalation to year 2022. The cost estimate includes allowances to address the resolution of the landmark status of a building on the site.

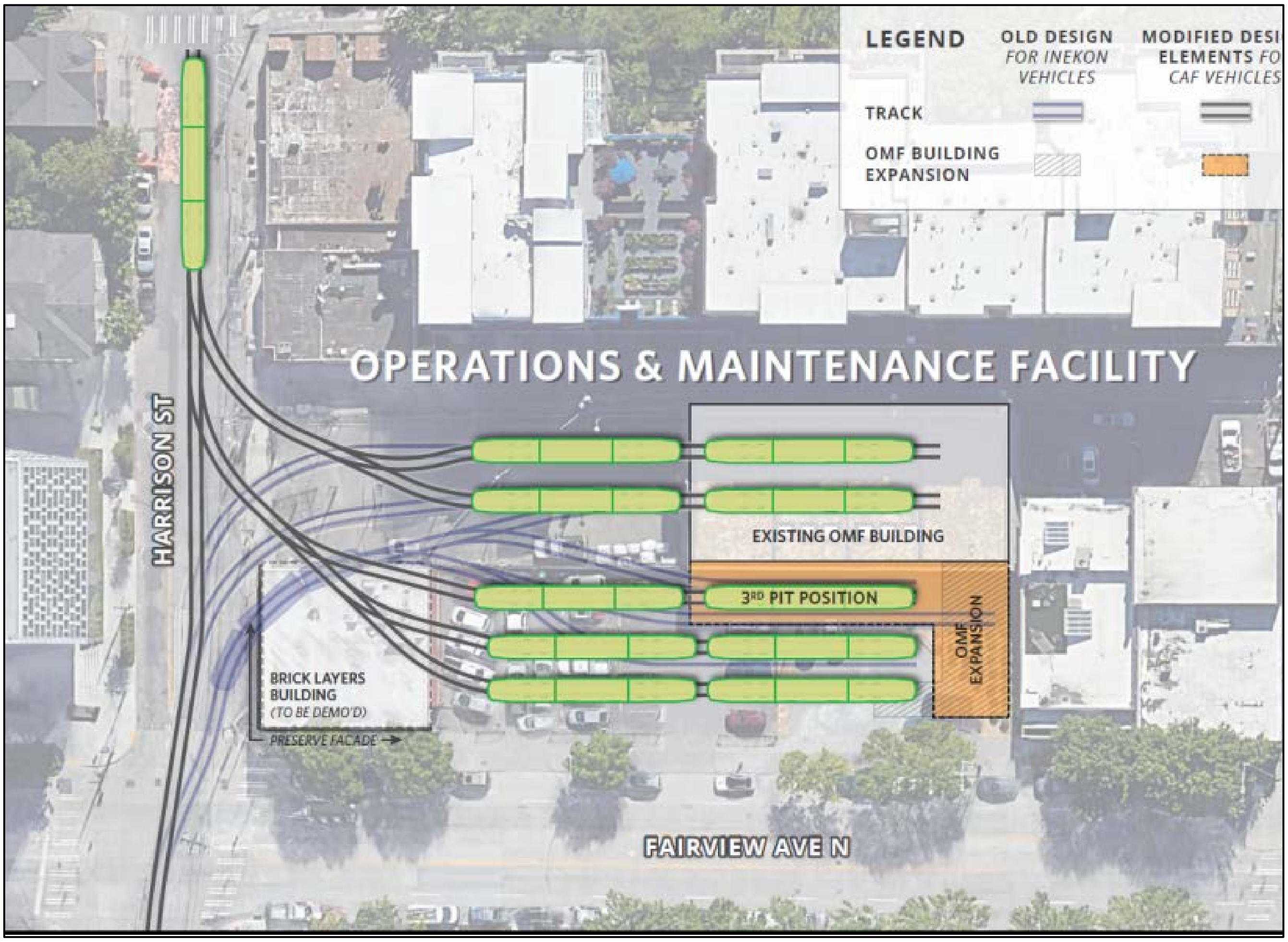

Figure 8 : Conceptual layout of track and OMF expansion at SLU OMF site.

8 BRIDGES

8.1 CHARACTERISTICS OF S. JACKSON STREET ROADWAY STRUCTURES

S. Jackson Street, between 2nd Avenue Extension S and 5th Avenue S, is supported by four early-20th century bridge structures and one replacement structure completed in 1987. These structures were evaluated as part of the design of the First Hill Streetcar line to determine their capacity to support the operation of the Inekon streetcar vehicles. Some strengthening was completed with the First Hill Streetcar line as a result of that analysis. Additional analysis is needed to determine the sufficiency of these structures to accommodate additional loading associated with the heavier CAF Urbos streetcar vehicles.

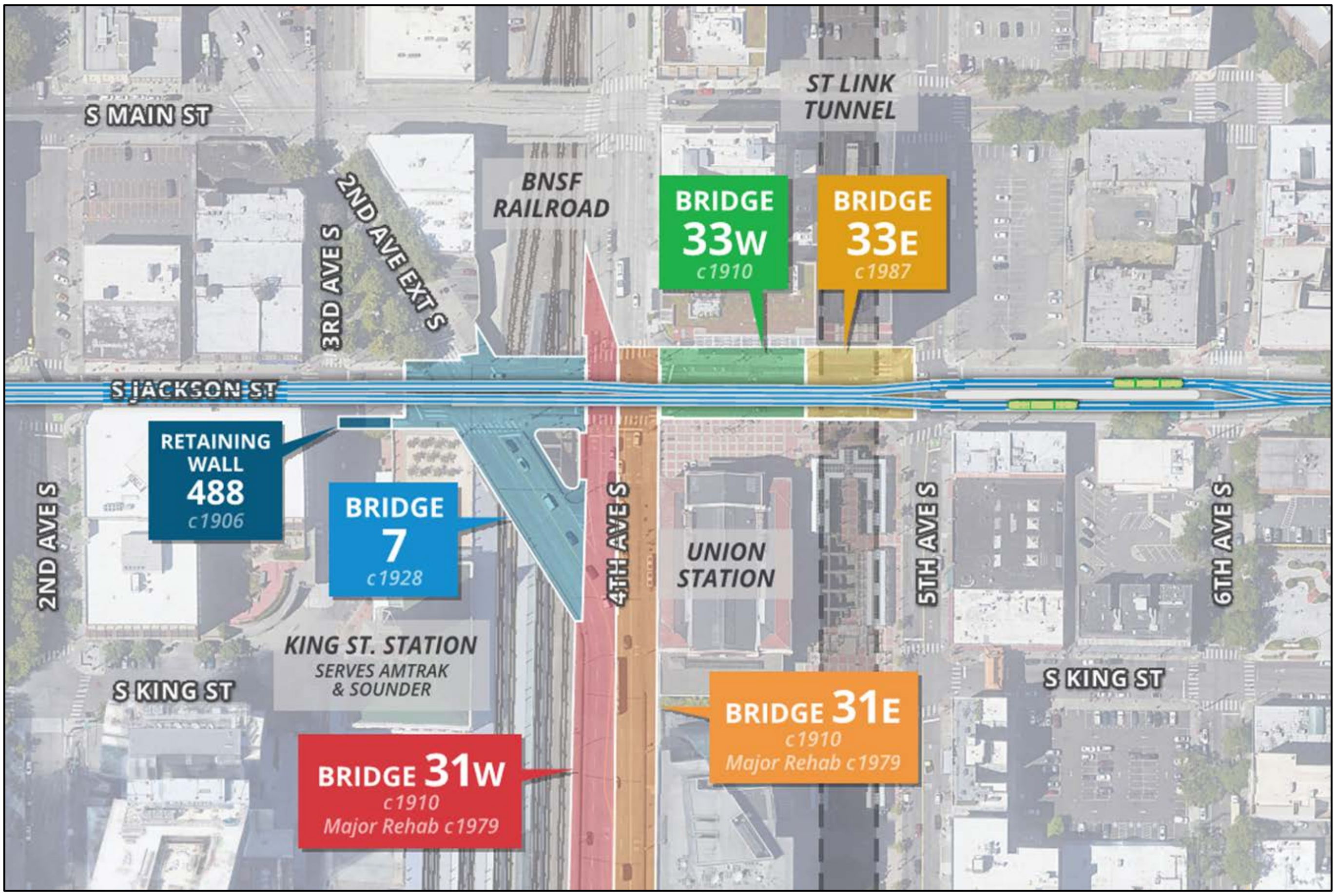

Figure 9 : Five bridge structures of various vintages support the S Jackson Street roadway and streetcar tracks between 2nd Ave Extension S and 5th Avenue S.

8.2 STRUCTURAL SCREENING & ANALYSIS APPROACH

This analysis included a preliminary screening to determine which structural members may require strengthening or replacement to accommodate the heavier CAF vehicles. The analysis approach was to scale available load rating factors from reports developed for the First Hill Streetcar project. To further develop the design, new load rating analyses, possibly informed by live load testing, would be used to refine the analysis of the structures and the determination of strengthening requirements.

8.3 STRUCTURAL RETROFIT CONCEPTS & COST ESTIMATES

The analysis identified the general strengthening type appropriate to each bridge member requiring strengthening. The bridge plans were used to compile approximate quantities. When a structural member required strengthening, it was assumed that the modification was for the full length of the member between supports unless noted otherwise. Cost data was taken from the previous FHS strengthening work where applicable. Other historical cost data was used where FHS costs are not applicable. Where strengthening does not appear to be feasible, it was assumed that some partial replacement of bridge elements would be required. A broad range was applied to unit costs to account for the conceptual nature of the screening, analysis, and identification of types of strengthening. The total cost of these structural retrofits is estimated to have a range from $4.4 M to $10.3 M, inclusive of estimating contingencies and escalation to year 2022.

9 COST ESTIMATES

9.1 COST ESTIMATE SUMMARY

The range of estimated costs to address conflicts or deficiencies associated with interface of the proposed CAF Urbos streetcar vehicles with existing and proposed Seattle Streetcar infrastructure is summarized by element below in **Table 1**. Some elements include a range of costs to reflect options in the conceptual design solution (e.g., tail tracks) or a range in the extent of scope required (e.g., bridges).

Table 1: Estimated Cost Range to Address Vehicle/Project Interface

Element	Total Cost (2022 $)	
	Low	High
Platforms	500,000	500,000
Tail Tracks	500,000	800,000
Maintenance Facility	5,600,000	5,800,000
Bridges	4,400,000	10,300,000
Total Cost	11,000,000	17,400,000

9.2 COST ESTIMATING METHODOLOGY

The vehicle/project interface analysis includes conceptual design to the equivalent of 10% design completion. While the conceptual design establishes that there are feasible design solutions to address conflicts or deficiencies, there are many details affecting cost to be developed during the progression of the design. To address this uncertainty, the cost estimates incorporate a standard approach to estimating contingencies that SDOT has developed to provide conservative estimates of costs that are in an early stage of project development. This estimating methodology is further described below. The cost estimates include an Engineer's Estimate of the direct cost of labor and materials based on the scope of work, estimated quantities, and typical unit costs for the work, with mark-ups for design allowance (design contingency), escalation (to 2022), construction contingency, design services, and construction management. The following percentages were used to estimate mark-up on the Engineer's Estimate:

Design Services	26% of EE (20% plus 30% contingency)
Construction Management	30% of EE (25% plus 20% contingency)
Mobilization and Traffic Control	26% of EE
Design Allowance* (aka design contingency)	30-50% of EE as detailed below
Escalation	20% (to 2022: 5%, 5%, 4.5%, 4%) applied to both the EE and the Design Allowance
Construction Contingency	20% of escalated EE and Design Allowance

*A 40% Design Allowance is typical for projects in the development phase. The Design Allowance was adjusted for this analysis as follows:

- Bridges – 50%, to reflect the assessment methodology and need for more detailed analysis
- Platforms – 25% to reflect SDOT experience with platform modifications
- Tail tracks – 30% to reflect straightforward scope, unlikely to change as design advances
- Maintenance Building – 40% (low end of range) 50% (high end of range)
- Maintenance Yard and Lead Track – 40%